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Improving the Environmental Impact Classification for Alien Taxa (EICAT): a summary of revisions to the framework and guidelines

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Abstract

The Environmental Impact Classification for Alien Taxa (EICAT) classifies the impacts caused by alien species in their introduced range in standardised terms across taxa and recipient environments. Impacts are classified into one of five levels of severity, from Minimal Concern to Massive, via one of 12 impact mechanisms. Here, we explain revisions based on an IUCN-wide consultation process to the previously-

published EICAT framework and guidelines, to clarify why these changes were necessary. These changes mainly concern: the distinction between the two highest levels of impact severity (Major and Massive impacts), the scenarios of the five levels of severity for the hybridisation and disease transmission mechanisms, the broadening of existing impact mechanisms to capture overlooked mechanisms, the Current (Maximum) Impact, and the way uncertainty of individual impact assessments is evaluated. Our aim in explaining this revision process is to ensure consistency of EICAT assessments, by improving the understanding of the framework.

Keywords
Alien species, impact assessment, impact mechanism, IUCN, non-indigenous species

Introduction

The Environmental Impact Classification for Alien Taxa (EICAT: Blackburn et al. 2014; Hawkins et al. 2015; IUCN 2020a, b) has been developed to quantify variation in the severity and type of environmental impacts generated by alien species. Semi-quantitative scenarios are used to categorise impacts caused by alien taxa on native species into one of five levels of severity – Minimal Concern (**MC**), Minor (**MN**), Moderate (**MO**), Major (**MR**), Massive (**MV**) (Fig. 1) – via one of 12 EICAT impact mechanisms: (1) Competition, (2) Predation, (3) Hybridisation, (4) Transmission of diseases to native species, (5) Parasitism, (6) Poisoning / toxicity, (7) Biofouling or other direct physical disturbance, (8) Grazing / herbivory / browsing, (9, 10, 11) Chemical, physical, or structural impact on ecosystem, (12) Indirect impacts through interaction with other species (see Table 1 in IUCN 2020a: Criteria used to classify alien taxa by EICAT impact category). Non-native species residing in the recipient environment can be negatively affected by the alien taxon as well, but EICAT only classifies impacts on the native biota. This classification system facilitates comparisons between impacts generated by alien species across geographic regions and taxonomic groups. Hawkins et al. (2015) provided guidelines for the application of the framework inspired by the IUCN Red List of Threatened Species (IUCN 2012, 2019).

EICAT has been used to undertake assessments of the environmental impacts of alien birds (Evans et al. 2016), amphibians (Kumschick et al. 2017; Measey et al. 2020), bamboos (Canavan et al. 2019), marine fishes (Galanidi et al. 2018), feral mammals (Hagen and Kumschick 2018) and gastropods (Kesner and Kumschick 2018), among others. Whilst these assessments demonstrated that EICAT can be effectively used to quantify and categorise the environmental impacts of alien species from different taxonomic groups, they also highlighted that aspects of the existing guidelines require refinement in order to improve the assessment process. In 2020, EICAT was officially adopted as the IUCN standard for classifying alien species in terms of their environmental impact. A new standard classification of the impacts of invasive alien taxa (IUCN 2020a), as well as new guidelines for using this standard classification (IUCN 2020b) have been developed based on an IUCN-wide consultation process to solve the

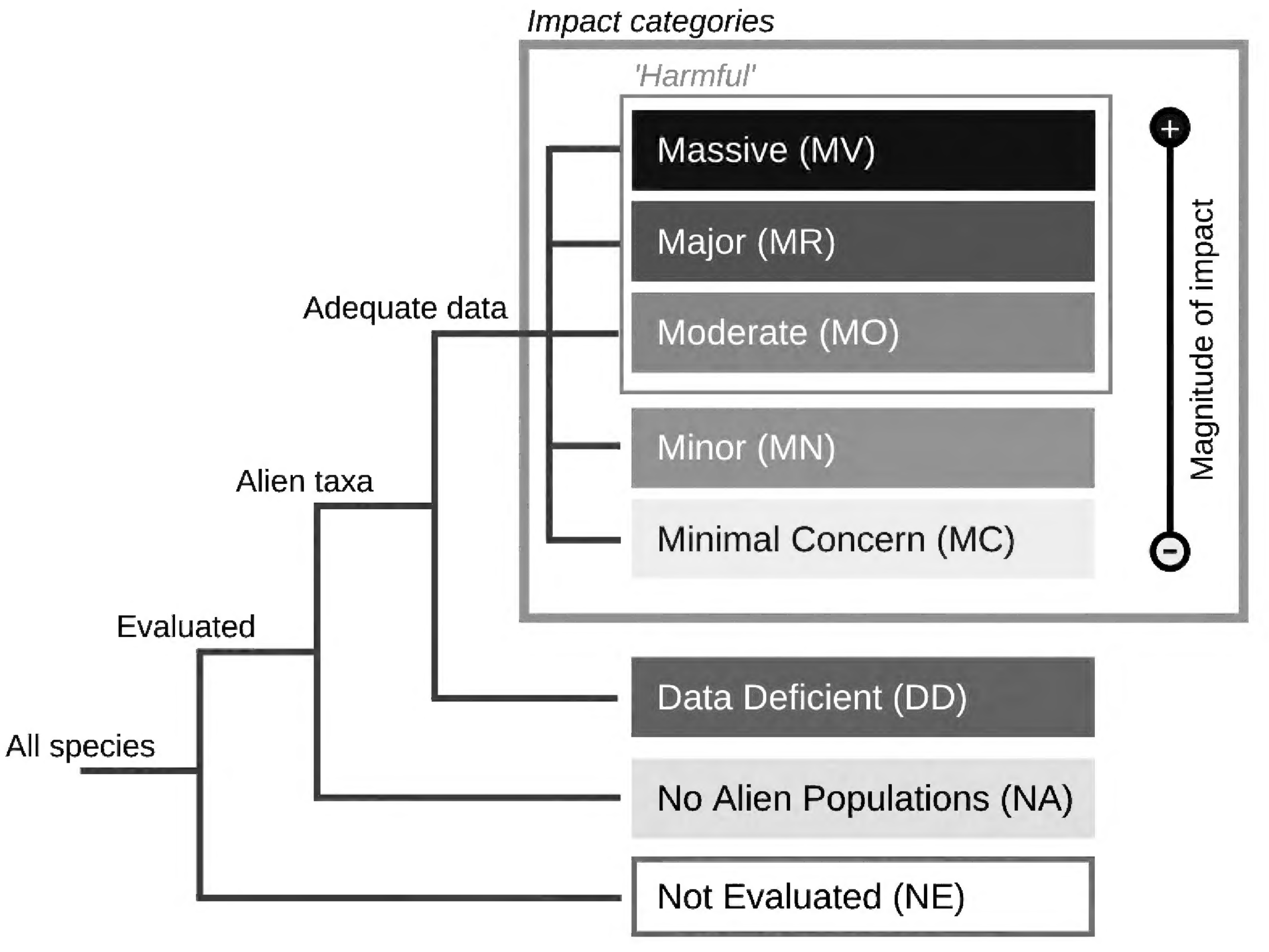

Figure 1. The different EICAT categories and the relationship between them. Reproduced from IUCN (2020a) IUCN EICAT Categories and Criteria, IUCN (Gland): page 10, https://doi.org/10.2305/IUCN.CH.2020.05.en, with permission from IUCN.

problematic aspects and improve the process: these documents update and replace the existing guidance documentation (Hawkins et al. 2015).

Here, we have explained the major changes made to the previous EICAT guidance and the reasons for these changes, so that the revision process is transparent. By detailing the reasoning behind the changes, we also aim to improve the general understanding of the framework, which is likely to result in an increased consistency in its use by different assessors. Therefore, while this guidance will be particularly useful to assessors already familiar with EICAT, we would also recommend it to assessors intending to use EICAT for the first time.

Definitions

'Fitness' has been replaced by 'Performance'

In the description of the **MN** impact magnitude and throughout, the term 'fitness' has been replaced by the term 'performance'. As fitness is usually defined as the number

of descendants provided by an individual to the next generations, changes in the individual fitness lead per definition to changes in native population sizes (**MO** impact) (Krimbas 2004, Hunt and Hodgson 2010). This is problematic, as in EICAT, **MN** impacts explicitly do not involve population level impacts. Performance, on the contrary, does not necessarily relate to offspring production and therefore does not imply **MO** impacts: it includes changes in the individual growth, reproduction, fecundity, survival, defense, immunocompetence, etc. **MN** impacts (i.e. impacts on the individual performance) can lead to population level impacts (**MO**, **MR** and **MV** impacts), but do not necessarily do so.

Population, sub-population, local population

The three most severe EICAT impact categories (**MO**, **MR** and **MV**) involve population level impacts to native taxon [causing declining populations of native taxon (**MO** impacts), or reversible and irreversible population extinctions (**MR** and **MV** impacts, respectively)]. To reflect the severe nature of these impacts and to assist efficient communication of high impacts, **MO**, **MR** and **MV** impacts have been grouped together under the term 'harmful' (Fig. 1). This follows a similar approach adopted by the IUCN Red List of Threatened Species (https://www.iucnredlist.org/), where native species in the three of the Red List categories [Vulnerable (VU), Endangered (EN) and Critically Endangered (CR)] are grouped under the term 'threatened'. The terms 'population', 'local population', 'sub-population' and 'global population' are widely used terms which might not always be understood in the same way (Wells and Richmond 1995): to avoid any confusion on what is meant in EICAT by 'population level impacts', these different terms have been clearly defined in the revised guidance.

Revised guidance

The relationship between a global population, a sub-population and a local population has been clarified (IUCN 2020a):

- A global population includes all individuals of a taxon
- A sub-population is a geographically or otherwise distinct group in the global population of a taxon
- A local population is a group of individuals within a sub-population of a taxon

Sub-populations are largely isolated from each other, whereas local populations within a sub-population are connected by frequent movements of individuals (Fig. 2). For EICAT assessments, population decline and extinction should be evaluated at least at the level of a local population (but can also happen at higher levels, such as sub-population or global population levels).

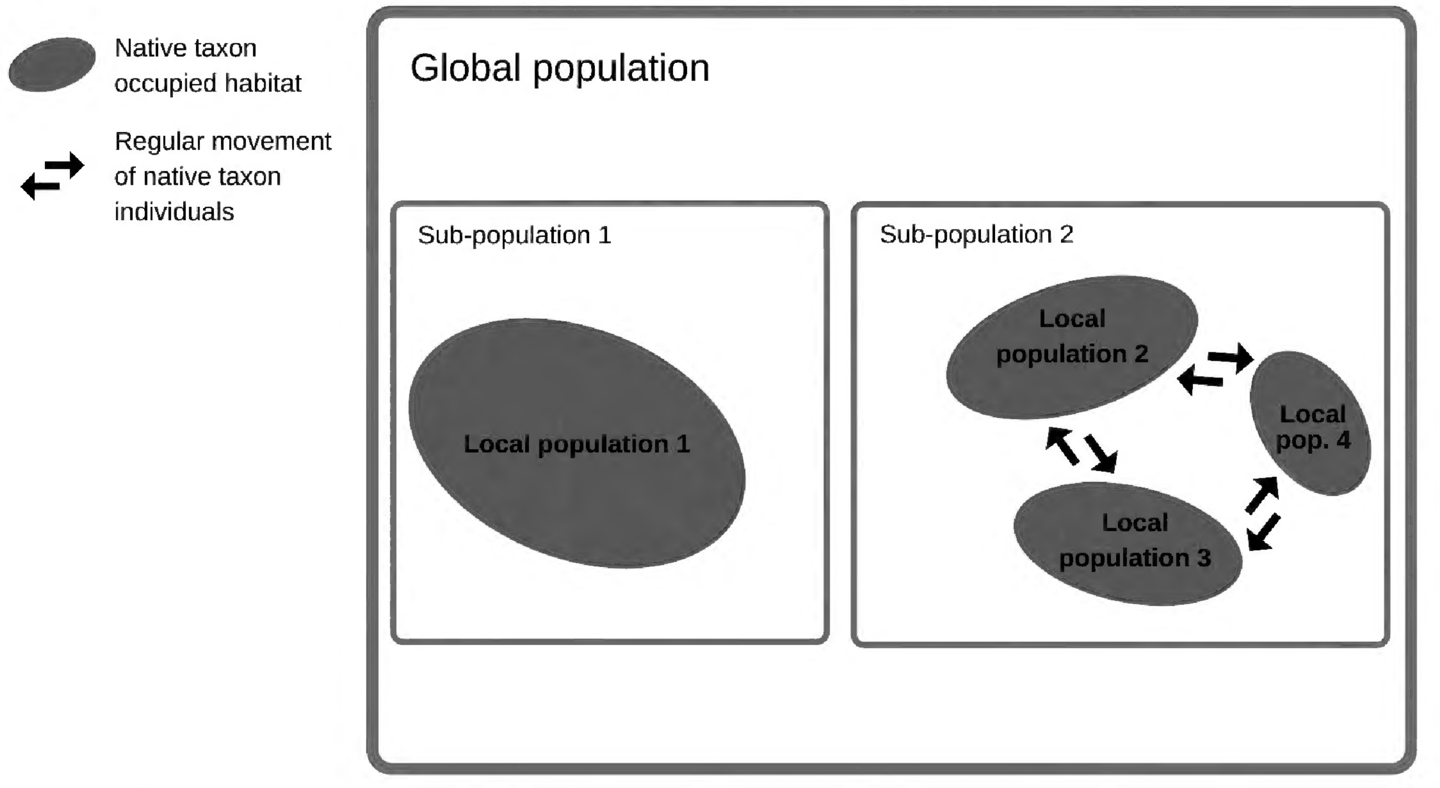

Figure 2. The relationship between a global population, sub-population and local population for the purposes of EICAT assessments. The global population includes all individuals of a taxon, a sub-population is a geographically or otherwise distinct group in the population, and a local population is a group of individuals within a sub-population. In this example, local population 1 includes all individuals within sub-population 1. Local populations 2, 3 and 4 are connected by frequent natural immigration, whereas sub-populations 1 and 2 are largely isolated from each other. Reproduced from IUCN (2020a) IUCN EICAT Categories and Criteria, IUCN (Gland): page 4, https://doi.org/10.2305/IUCN.CH.2020.05.en, with permission from IUCN.

To show impacts at the native population level (**MO**, **MR** or **MV**), studies should understand the structure and dynamics of the populations being considered through the assessment. The individuals comprising a local population are often spatially grouped into smaller units (termed patches, aggregates, clusters, herds, etc.), which are naturally dynamic (i.e. appearance of new patches and disappearance or expansion of existing patches; Hanski 1994). Impact studies and EICAT assessors should be careful not to consider individual patches as local populations when evaluating the magnitude of the impact caused by the alien taxon. Studies should also ideally have attempted to understand the natural dynamics of the native local populations, to avoid incorrectly interpreting changes due to natural variation as impacts of the alien taxon (e.g. Schooley and Branch 2009; Hanski et al. 2017; the guidelines of the IUCN Red List of Threatened Species (IUCN 2012, 2019) provide examples of different population dynamics, such as extreme fluctuations or severely fragmented populations).

Observations or experiments are sometimes carried out on native local 'populations' that are not reproducing (e.g. common garden experiments for plants or mesocosm experiments). In EICAT, impacts can be reported at the population level (**MO**, **MR** or **MV**) only when observations or experiments are carried out on native self-sustaining populations. Ideally, changes in native population dynamics should have been happening over several generations to conclude population level impacts (**MO**, **MR** or **MV**):

for instance, to confidently detect population level impacts, it might not be sufficient to observe fewer native plant individuals in the same generation, as these losses could be compensated for by seedling recruitment. Therefore, in the cases of non-self-sustaining native populations, one can only infer impacts on individual performance (**MN**).

Impact categories

Determining whether an impact is Major (MR) or Massive (MV) under EICAT

Determining whether the impact of an alien taxon on a native taxon is **MR** or **MV** under EICAT is established by assessing whether the impact is reversible. Both **MR** and **MV** impacts result in native taxon extinctions: a local population extinction that is reversible is classified as an **MR** impact, whilst an irreversible local population extinction is an **MV** impact. Under the previous EICAT guidance, the assessor is required to determine whether the impact of the alien taxon is likely to be reversible through management actions (for example by considering the logistics associated with extirpating or eradicating the alien taxon, re-introducing the native taxon and / or restoring native habitats). In cases where the effort or cost required to reverse the changes caused by the alien taxon were beyond capabilities, the impact would be judged irreversible (i.e. it would be assessed as an **MV** impact), even if in theory it might be possible to re-establish the native local population.

Determining whether management actions are likely to enable the native taxon to re-colonise the area is an unrealistic demand of the assessor. This is very difficult to establish in an EICAT assessment procedure and is usually not discussed in the original impact reports used in the EICAT process: it would inevitably introduce new causes of uncertainty and subjectivity.

Revised guidance

The requirement to evaluate the reversibility of a native taxon extirpation through management actions has been removed from the guidance documentation. To determine whether an impact is **MR** or **MV**, the assessor must instead apply the hypothetical scenario which assumes that the alien taxon is eradicated from the location where it caused the extinction of a native local population, regardless of whether this eradication is feasible or if the native taxon could be re-established with additional effort:

- A local population extinction is reversible (an **MR** impact) if the native taxon would most likely return to the community from which it was extirpated within 10 years or 3 generations of the native taxon, whichever is longer, under either of the following conditions; (1) naturally [e.g. individuals migrating from another local population (of the same sub-population) recolonising the area], or (2) assisted by human re-introductions, either intentionally or unintentionally, but only where the re-introductions were occurring at a similar rate before the alien taxon

led to the native taxon local population extinction, and the re-introductions are not for conservation purposes. Examples for the second condition include cases where individuals of a native mussel are frequently (unintentionally) transported via boats to the place where the local population of this native mussel went extinct, or cases where a native fish is periodically (and intentionally) restocked for fishing in the lake where the local population of this fish went extinct. Therefore, re-introductions assisted by humans that were not already in place at the time the alien taxon led to the local population extinction and would require extra effort (e.g. re-introductions from captivity or from other areas) are not considered as reversible changes.

- A local population extinction is irreversible (an **MV** impact) if the native taxon is not likely to return to the community within 10 years or 3 generations of the native taxon, whichever is longer, without additional human assistance that was not already in place at the time the alien taxon led to the local population extinction. Local extinctions are irreversible when there is no propagule influx of the native taxon (e.g. global extinction, disconnection of the local population), or when the alien population changes the environment, making it unsuitable for the native taxon.

Local extinctions which, under the previous guidance, were considered irreversible (**MV**) because of practical constraints or inability to either eradicate the alien or restore the native habitats, should be re-classified as **MR** impacts, if it is possible for the native taxon to return to the community naturally or assisted by human re-introductions already in place before the alien taxon led to its local population extinction. Local extinctions which were considered irreversible (**MV**) because the native taxon was globally extinct, because of a disconnection of the local population, or because of changes in the habitat characteristics due to the alien, should remain classified as **MV** under the revised guidance. Local extinctions which were classified as **MR** because it was judged logistically feasible to re-introduce the native taxon with extra effort (i.e. with measures not already in place before the alien taxon led to the native taxon extinction) or by restoring the habitat modified by the alien, should be considered irreversible and re-classified as **MV** under the revised guidance.

Impact mechanisms

Broadening of impact mechanisms in order to capture all types of impacts

EICAT considers that impacts caused by alien taxon to a native taxon can occur through 12 EICAT impact mechanisms, which align with those identified in the IUCN Global Invasive Species Database (GISD) (http://www.iucngisd.org/gisd). In the previous EICAT guidance, these mechanisms were: (1) Competition, (2) Predation, (3) Hybridisation, (4) Transmission of diseases to native species, (5) Parasitism, (6) Poisoning / toxicity, (7) Biofouling, (8) Grazing / herbivory / browsing, (9, 10, 11) Chemical, physical, or structural impact on ecosystem, (12) Interaction with other alien species (Hawkins et al. 2015). Impact mechanisms describe the way a native taxon

is affected by an alien taxon: e.g. by feeding on plants, alien herbivores can affect native plants through 'Grazing', and at the same time they can affect native insects or ground-nesting birds through 'Chemical, physical, or structural impact on ecosystem', because of above-ground plant biomass removal.

Indirect impacts to native taxon were not completely captured by these 12 mechanisms. In indirect impacts, the alien taxon does not directly interact with the impacted native taxon: it affects the native taxon by modifying another factor of the environment, which can be biotic (a population of another alien or native taxon), or abiotic (e.g. water or soil composition). In the 12 mechanisms, indirect impacts occurring through changes in abiotic factors are captured by the mechanism 'Chemical, physical, or structural impact on ecosystem'. Indirect impacts through changes to biotic factors can occur **a)** when the alien taxon facilitates the negative effect of an intermediate species on the native taxon of interest. This is the case in the 'Transmission of disease' or in the 'Interaction with another alien species' mechanisms, where the alien facilitates the negative impact respectively of a parasite (by vectoring it) or of another alien species. However, other examples of such indirect impacts exist, and were not described by any mechanisms of the previous guidance: for instance, on San Miguel and Santa Cruz Islands (California Channel Islands), an introduced pig (*Sus scrofa*) population enabled the colonisation by mainland golden eagles (*Aquila chrysaetos*) and caused an increase in their population by providing a supplemental food source, leading the golden eagle population to start feeding on the native fox (*Urocyon littoralis*) population and causing its decline (Roemer et al. 2001, 2002). In this example, the alien pig had an indirect impact on the native fox, by facilitating the impact of the golden eagle. Indirect impacts can also occur when **b)** the alien taxon inhibits a positive effect of an intermediate species on the native taxon of interest. This is the case in the 'Competition' mechanism, where the alien taxon decreases the availability of a resource and thereby decreases the benefits brought by this resource to the native taxon. However, other mechanisms for this type of indirect impacts were previously ignored as well. In North American forests, for example, the European plant garlic mustard (*Alliaria petiolata*) has been found to release antifungal phytochemicals which eliminate the activity of native arbuscular mycorrhizal fungi and suppress the growth of native tree seedlings by disrupting their mutualistic associations (Stinson et al. 2006; Callaway et al. 2008). Such impacts are not described by any mechanism and cannot be systematically and consistently classified.

With respect to direct mechanisms, impacts occurring through direct physical disturbances, such as vegetation trampling or tree rubbing, were not captured either. Alien populations of ungulates often cause direct physical disturbances: for instance, an alien population of the Asian elephant (*Elephas maximus*) on the Andaman Islands (India) contributed to the declines of several native plant populations by heavily grazing upon them, but also by uprooting and debarking trees (Ali 2004). In such impacts, native individuals are not indirectly affected by a change in some environmental characteristics (impact on ecosystem), but are affected by their direct interaction with alien individuals.

Revised guidance

To capture all indirect impacts occurring through changes to biotic factors, the mechanism 'Interaction with other alien species' has been amended to 'Indirect impacts through interaction with other species' and the semi-quantitative scenarios updated accordingly (see Table 1).

Unlike the direct mechanisms of 'Predation', 'Grazing / herbivory / browsing' or 'Parasitism', the direct impacts caused by physical disturbances (e.g. vegetation trampling) do not concern trophic interactions. The existing 'Biofouling' mechanism is also a direct mechanism not concerning trophic interactions but occurring through a physical disturbance of native individuals: therefore, the mechanism 'Biofouling' has been amended to 'Biofouling or other direct physical disturbance', to capture all types of impacts occurring through direct physical disturbances.

These extensions of two mechanism definitions allow the classification of impacts that were not captured in a systematic way under the previous guidance: impacts falling into these new definitions, and previously classified into unsuited mechanisms, should be re-classified into one of these two extended mechanisms.

Refinement and clarification of the criteria for the mechanism 'Transmission of disease'

In the 'Transmission of disease' mechanism, the alien taxon acts as a vector of a (native or alien) disease agent (e.g. virus, bacteria or prion) or parasite which impacts upon native taxa. When we evaluate the impact of the alien taxon through 'Transmission of disease', we evaluate its impact as a vector [i.e. the increase in the spread of the disease agent/parasite (hereafter, parasite) caused by the alien vector impacts the native taxon]. However, evidence of the alien taxon being a host is more frequently available than evidence of the alien taxon being a vector. For instance, the chytrid fungus (*Batrachochytrium dendrobatidis*), which has contributed to global amphibian declines, has been shown to be transmitted by alien amphibians populations to the native ones (e.g. Fisher and Garner 2007; Miaud et al. 2016); yet, most studies only show that alien amphibian populations are reservoirs for the chytrid fungus instead of showing that they transmit the disease to the native populations (Measey et al. 2016). The responsibility of the alien taxon for disease spread and observed impact is difficult to evaluate from such evidence.

Revised guidance

Based on the available types of evidence for this mechanism, the information required to classify impacts through 'Transmission of disease' has been clarified. For an impact to be classified as **MO**, **MR** or **MV**, the following information is needed: an impact on

the native population [e.g. a decline (**MO**) or a local extinction (**MR/MV**)] has to be observed and the alien taxon has to be shown to be a host of the parasite at the same time and space as the native population (based on Kumschick et al. 2017). When the only available evidence is that the alien taxon is a host (or a vector) of a disease that affects individuals, the impact should be scored as **MN**: the extent of the impact on the native population is not shown or studied, so we can only suppose that the performance of the infected individuals has been affected. Impacts are classified as **MC** when the disease or parasite carried by the alien taxon was not found in the native taxa, or when the disease or parasite was found in the native taxa but shown to be harmless to the native individuals. The semi-quantitative scenarios of the 'Transmission of disease' mechanism have been updated accordingly (see Table 1).

Establishing whether the alien taxon is the only (or main) vector of the parasite in the recipient environment, or whether multiple vectors are present and are aiding the spread of the parasite, helps to evaluate the impact of the alien vector. If the alien taxon is the only vector, the impact of the alien taxon equates to the impact of the parasite. If the alien taxon is not the only vector of the parasite, the impact of the alien taxon equates to the impact caused by the increase in the spread of the parasite due to the alien taxon.

If the parasite vectored by the alien taxon is also an alien in the area of interest, separate EICAT assessments need to be performed for it, under the mechanism 'Parasitism'. In cases where the alien vector is the only vector present in the recipient environment, the same impact magnitude would be recorded for the alien vector and for the alien parasite (because if either of them were absent, the observed impact would not occur). In cases where the alien vector is increasing the spread of an alien parasite, the impacts of the alien parasite and of the alien vector might be of different magnitudes (but the impact of the alien parasite will always be the same or higher than the impact of the alien vector in this specific mechanism).

These updates show how to apply the information usually available regarding the 'Transmission of disease' mechanism: impact reports showing that the alien is a host of a parasite causing damage to the individual performance or population of a native species can now be classified in a consistent way. Such impact reports might have been classified differently under the previous guidance, because of a lack of solid evidence showing that the alien taxon was transmitting the parasite to native species: these reports should be re-classified based on the new criteria.

Revised scenarios to describe the severity of 'Hybridisation' impacts

For all impact mechanisms, the five semi-quantitative scenarios categorising severity should follow the same general logic. However, the semi-quantitative scenarios used to describe the severity of 'Hybridisation' impacts are not in-line with those used to describe the severity of impacts associated with other mechanisms, because they focus on the viability of the hybrid offspring, rather than on the native individuals. The semi-quantitative scenarios are also based on hypothetical (projected) impacts, in-

stead of on observed impacts. Indeed, these scenarios assume that as soon as hybrids can reproduce with the native population, the latter is inevitably lost. In so doing, they ignore the possibilities that hybrid individuals may be removed from the population, that hybrids may only reproduce with other hybrids (assortative mating), that stable hybrid and native populations may coexist, that backcrossing processes may occur, or simply that hybridisation may not have been happening for long enough for the native population to go extinct. For example, the ruddy duck (*Oxyura jamaicensis*) hybridises with the endangered white-headed duck (*Oxyura leucocephala*) in Spain, but even though hybrids are fertile and produce viable offspring, early control programmes of the alien population and the hybrids allowed to avoid a decline in the white-headed duck population (Muñoz-Fuentes et al. 2007). The Asian sika deer (*Cervus nippon*) is known to hybridise with the native red deer (*Cervus elaphus*) in Scotland and England, but local red deer populations show very different levels of hybridisation. The sika deer have led to population declines in some locations where high proportions of hybrids were detected (e.g. in Kintyre Peninsula), but not in others, where a low frequency of hybrids was detected in large sample sizes, revealing past hybridisation followed by extensive backcrossing (e.g. in Lake District and North Highlands) (Smith et al. 2018).

Revised guidance

Each hybridisation event between native and alien or hybrid individuals reduces the reproduction rate of the pure native taxon, which can lead to a decline in population size or to local extinction, depending on the frequency of the hybridisation events and on whether hybrids are fertile. The criteria are now based on observed instead of projected impacts: hence, cases where hybrids are fertile but did not lead to local extinctions would no longer be classified as **MR** or **MV** (but maximum as **MO**). With increasing impact severity, the reproduction rate of the pure native taxon reduces, which may lead to declining populations of a native taxon (**MO** impacts) or to reversible and irreversible species extinctions (**MR** and **MV** impacts), depending on the frequency of the hybridisation events (see Table 1).

'Hybridisation' impacts classified using the previous guidance can be adapted to the revised guidance as follows:

- Impacts initially classified in the **MC** or **MN** categories can remain classified in the **MC** or **MN** categories, respectively;
- Impacts initially classified in the **MO** category because hybridisation is regularly observed in the wild and has led to a decline of the pure native population can remain classified in the **MO** category. In contrast, impacts initially classified in the **MO** category only because hybrids are vigorous but sterile, but with no decline of the pure native population observed, should be re-classified in the **MN** category;
- Because, in the previous guidance, the criteria of the **MR** category did not describe any replacement of the pure native population, impacts initially classified in the **MR** category should be re-classified in the **MO** category;

Table 1. Criteria used to classify alien taxa by EICAT impact category (**MC**, **MN**, **MO**, **MR**, **MV**) for the three modified mechanisms: Indirect impacts through interaction with other species, Transmission of disease to native species and Hybridisation. Reproduced from IUCN (2020a) IUCN EICAT Categories and Criteria, IUCN (Gland): pages 13–16, https://doi.org/10.2305/IUCN.CH.2020.05.en, with permission from IUCN.

	Massive (MV)	Major (MR)	Moderate (MO)	Minor (MN)	Minimal Concern (MC)
Categories should adhere to the following general meaning	Causes local extinction of at least one native taxon (i.e., taxa vanish from communities at sites where they occurred before the alien arrived), which is naturally irreversible; even if the alien taxon is no longer present the native taxon cannot recolonise the area	Causes local or subpopulation extinction of at least one native taxon (i.e., taxa vanish from communities at sites where they occurred before the alien arrived); which is naturally reversible if the alien taxon is no longer present	Causes population decline in at least one native taxon, but no local population extinction	Causes reduction in individual performance (e.g., growth, reproduction, defence, immunocompetence), but no decline in local native population sizes	Negligible level of impact; no reduction in performance (e.g., growth, reproduction, defence, immunocompetence) of individuals of native taxa
Mechanisms					
Indirect impacts through interaction with other species	Interaction of an alien taxon with other taxa leading to indirect impacts (e.g., pollination, seed dispersal, apparent competition) causing local extinction of one or several native taxa, leading to naturally irreversible changes that would not have occurred in the absence of the alien taxon	Interaction of an alien taxon with other taxa leading to indirect impacts (e.g., pollination, seed dispersal, apparent competition) causing local population extinction of at least one native taxon; changes are naturally reversible but would not have occurred in the absence of the alien taxon	Interaction of an alien taxon with other taxa leading to indirect impacts (e.g., pollination, seed dispersal, apparent competition) causing a decline of population size of at least one native taxon, but no local population extinction; impacts would not have occurred in the absence of the alien taxon	Interaction of an alien taxon with other taxa leading to indirect impacts (e.g., pollination, seed dispersal, apparent competition) affecting performance of native individuals without decline of their populations; impacts would not have occurred in the absence of the alien taxon	Interaction of an alien taxon with other taxa leading to indirect impacts (e.g., pollination, seed dispersal, apparent competition) but reduction in performance of native individuals is not detectable
Transmission of disease to native species	Transmission of disease to native taxa resulting in local extinction of at least one native taxon; changes are naturally irreversible	Transmission of disease to native taxa resulting in local population extinction of at least one native taxon; naturally reversible when the alien taxon is no longer present	Transmission of disease to native taxa resulting in a decline of population size of at least one native taxon, but no local population extinction; disease is severely affecting native taxa, including mortality of individuals, and it has been found in native and alien co-occurring individuals (same time and space)	Transmission of disease to native taxa affects performance of native individuals without leading to a decline of their populations; alien taxon is a host of a disease which has also been detected in native taxa and affects the performance of native taxa	The alien taxon is a host or vector of a disease transmissible to native taxa but disease not detected in native taxa; reduction in performance of native individuals is not detectable
Hybridisation	Hybridisation between the alien taxon and native taxa leading to the loss of at least one pure native local population (genomic extinction); pure native taxa cannot be recovered even if the alien and hybrids are no longer present	Hybridisation between the alien taxon and native taxa leading to the loss of at least one pure native local population (genomic extinction); naturally reversible when the alien taxon and hybrids are no longer present	Hybridisation between the alien taxon and native taxa is regularly observed in the wild; local decline of populations of at least one pure native taxon, but pure native taxa persist	Hybridisation between the alien taxon and native taxa is observed in the wild, but rare; no decline of pure local native populations	No hybridisation between the alien taxon and native taxa observed in the wild (prezygotic barriers), hybridisation with a native taxon is possible in captivity

- Impacts initially classified in the **MV** category because hybridisation is common in the wild and /or because hybrids are fully vigorous and fertile should be:

- re-classified in the **MO** category if hybridisation has led to a decline in the pure native taxon but no replacement of the pure native population;
- re-classified in the **MR** category if hybridisation has led to the replacement of the local pure native population, but the native pure bred population can recover (either naturally or assisted by human re-introductions already in place before the alien taxon led to the local population extinction) if the alien and hybrids are no longer present;
- remain classified in the **MV** category if hybridisation has led to the replacement of the local pure native population, and the native pure bred population cannot recover (either naturally or assisted by human re-introductions already in place before the alien taxon led to the local population extinction) even if the alien and hybrids are no longer present.

Overall impact of an alien taxon

Distinction between spatial scale of assessments and geographic scale of assessments

The previous guidelines independently addressed the concepts of spatial scale of assessments and geographic scale of assessments. The term 'spatial scale of assessments' is used in the context of an individual EICAT assessment (based on one impact observation, or study), whereas the term 'geographic scale of assessments' is used in the context of the overall classification of an alien taxon. While these terms are used at different stages of the assessment process, they might be confused, as they both involve spatial aspects of assessments. The distinction between the two terms is made clear in the revised guidance.

Spatial scale of assessments: The term spatial scale of assessments relates to the evidence of impacts being assessed using the EICAT Categories and Criteria. Impacts caused by alien taxa need to be observed or investigated at an appropriate spatial and temporal scale, over which the original native communities can be characterised. Assessments based on evidence generated at spatial or temporal scales that are very different to the scales over which the local native population can be characterised are likely to be subject to greater uncertainty.

Geographic scale of assessments: Where impacts are assessed based on evidence from across an alien taxon's global introduced range, the geographic scale of the maximum recorded impact would be 'Global'. However, where impacts are assessed based on evidence from a single country to which an alien taxon has been introduced (excluding impacts from areas of its alien range in other countries), the geographic scale of the maximum recorded impact would be 'National' (Fig. 3). IUCN will only review and display global EICAT assessments on their website.

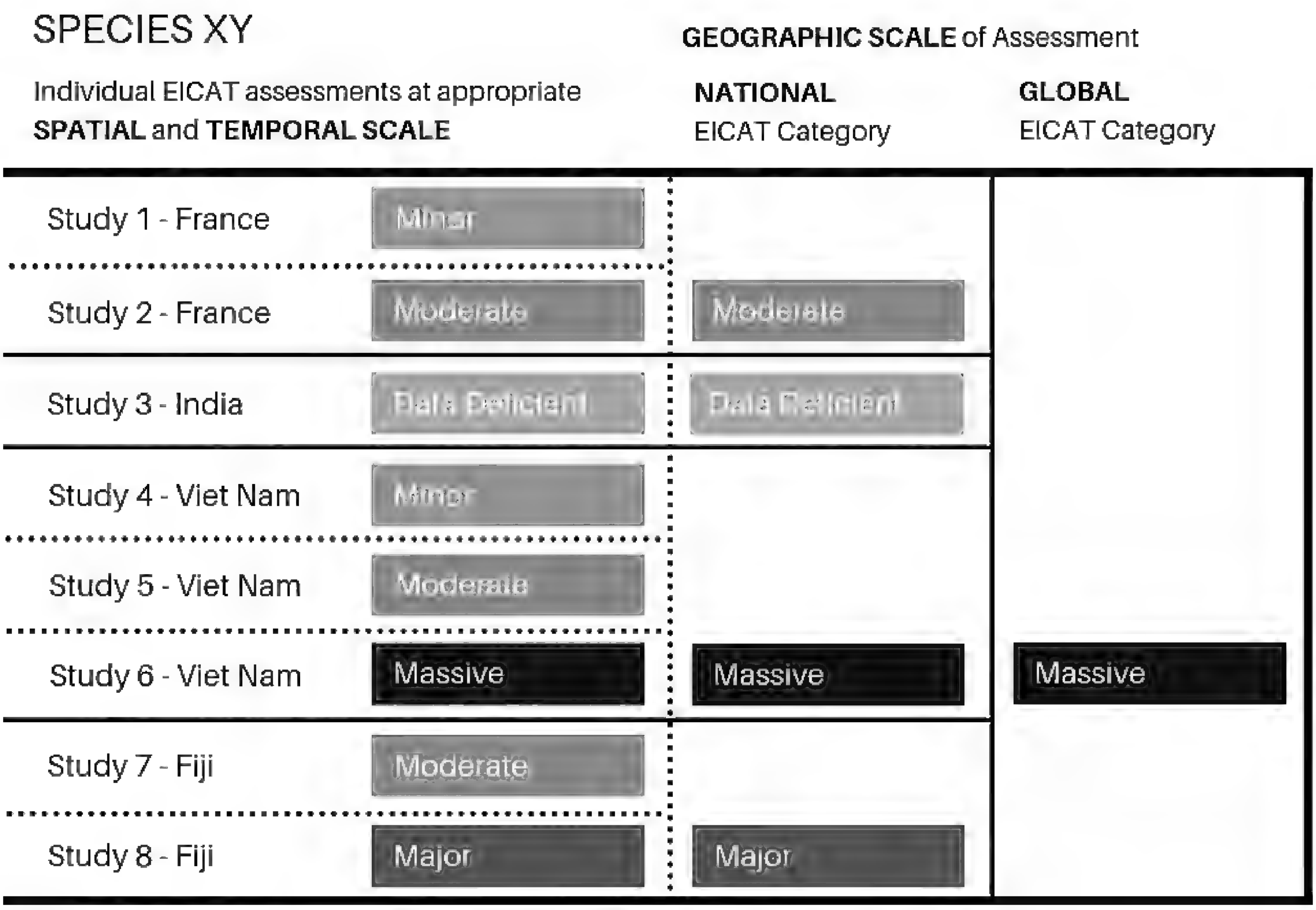

Figure 3. How data from individual EICAT assessments of the impacts of a hypothetical alien taxon (species XY) inform the EICAT Category to which the taxon is assigned at national and global scales. The global assessment categorises the taxon based on its highest impact anywhere [in this case, a Massive (**MV**) impact in Vietnam]. National scale assessments are based only on impacts reported from those countries [e.g. Major (**MR**) for Fiji]. Data Deficient (**DD**) in India indicates that the alien taxon was assessed but no impact reports from India were found. Reproduced from IUCN (2020a) IUCN EICAT Categories and Criteria, IUCN (Gland): page 20, https://doi.org/10.2305/IUCN.CH.2020.05.en, with permission from IUCN.

No longer recording Current (Maximum) Impact

Under the previous guidance, a dual assessment of the alien taxon's impacts was required (Hawkins et al. 2015):

- Maximum Recorded Impact (**MC**, **MN**, **MO**, **MR** or **MV**)
- Current (Maximum) Impact: the severity of impacts associated with an alien taxon's current impacts on a native species (at the time of the EICAT assessment) (**MC**, **MN**, **MO**, **MR** or **MV**)

The rationale here was that the two measures of impact severity could be compared to demonstrate whether the impacts of an alien taxon were increasing or decreasing over time. For instance, an impact could be downgraded to a lower magnitude once management practices had been established to control the alien population.

While downgrading or upgrading an impact to lower or higher magnitudes can be informative for the impact caused by a specific alien population, downgrading or upgrading

the overall impact of an alien taxon with multiple introduced populations is not straightforward and might lead to the loss of information on impacts, for the following reasons:

- Different introduced populations of the alien taxon are likely to vary over time in different ways: the same reduction or increase in the impact magnitude will probably not be observed in all its introduced populations. It is difficult to define in such cases how to treat the different scenarios with one global Current Impact score.
- Moreover, it is unclear when an impact should be considered as 'current' when considering the overall impact of an alien taxon (i.e. it is difficult to define a reasonable time scale over which impact magnitudes should be re-evaluated).
- Finally, information on the variation of impacts over time will likely not be available for most of the introduced populations of the alien taxon. It is unclear if potential differences in recent impact reports are the result of temporal changes in impact magnitudes.

Revised guidance

The requirement to assess an alien taxon's Current Impact has been removed: an assessment of the alien taxon's Maximum Recorded Impact is still required, which equals the taxon's EICAT Classification (as in Kumschick et al. 2020). EICAT is an evidence-based scheme: the classification of an alien taxon is only based on its observed impacts (or impacts inferred based on evidence), but potential, hypothetical or projected impacts are not assessed by the framework (IUCN 2020a).

Dealing with uncertainty

The assessor should assign each (relevant) impact report to its most likely impact category and assign a level of confidence to this assessment (high, medium or low), depending on the likelihood of the assigned impact category being correct. In the previous guidance, the factors listed as potentially reducing the assessors' confidence in the impact magnitude assigned to an impact observation included: the availability, reliability and type of data used as evidence of impacts, the spatial scale over which data were collected, the ease of interpretation of the available data, and whether or not all available data were in agreement with respect to the magnitude of recorded impacts.

The previous guidance did not address three important sources of uncertainty in EICAT assessments (see also Probert et al. 2020):

- **Confounding effects:** The presence of confounding effects is a frequent source of uncertainty in impact reports when changes are happening at the local population level (**MO**, **MR** or **MV**). Large-scale phenomena such as changes in native population dynamics usually do not allow an 'ideal' experimental set-up with control situations to exclude the possibility that other biotic or abiotic factors have caused or contributed to the observed impact (Kumschick et al. 2015, Christie et

al. 2019). It is therefore often difficult to distinguish whether an alien taxon is the driver of these changes, or whether confounding effects are at play. For instance, when a decline of a native taxon is observed but multiple stressors – including the alien taxon – act on that species, it is possible that the observed decline would have happened in the absence of the alien taxon. The impact caused by the alien taxon might therefore be lower than the one assigned (e.g. **MO**), if the decline would have happened anyway: the presence of other stressors can reduce the confidence in the assigned impact category. Conversely, when no other stressor is known to act on the impacted native taxon, the alien taxon is more likely to be responsible for the observed change.

- **Study design:** Impact studies are rarely designed to determine which impact magnitude is caused by the alien taxon based on the EICAT criteria (i.e. at which level of organisation are the native taxa affected by the alien taxon). Therefore, even in well-designed impact studies, uncertainty can exist regarding the impact magnitude that has been assigned to the impacts they report. For instance, some studies focus only on one particular level of impact (e.g. the individual performance) and are not investigating higher levels of impact (e.g. whether the impact on the individual performance is affecting the size of the population) even when these are likely (Probert et al. 2020). In such cases, the assessor should be aware that the study design creates uncertainty: the 'true' impact magnitude could be higher than the one assigned, if the alien causes a decline in the native population. Hence, these impacts cannot be classified as **MN** impacts with high confidence, as the **MN** category corresponds to impacts at the individual performance level and no impact at the population level (IUCN 2020b). In contrast, impact reports from study designs that describe an impact at the individual performance level, and which would have allowed detection of an impact at higher levels, can be classified as **MN** with high confidence regarding the 'Study design'.
- **Temporal scale:** Studies performed over time periods that are too short to capture the changes in a native population might lead to an over- or under-estimation of the severity of an impact. As previously explained, a study investigating impacts at the native population level (**MO**, **MR** or **MV**) should be performed at a temporal scale that allows changes in the dynamics of native populations to be captured, over several generations.

Revised guidance

The revised guidance for the confidence classification distinguishes between five sources of uncertainty in EICAT assessments: confounding effects, study design, data quality and type, spatial and temporal scales, and coherence of evidence (see Probert et al. 2020). The source 'Data quality and type' addresses the uncertainty associated with the use of inferred information in the assessment, but also the un-

certainty associated with the way the impact observation is communicated in the report. For instance, if no detail is provided on the way the observation or experiment has been performed in the report, the assessor cannot evaluate the relevance of the spatial/temporal scale or of the study design. The guidance also specifies how each of these sources can affect the assessor's level of confidence in their assessment, and in which circumstances these sources would lead to a high, medium or low score (Table 2).

Table 2. Guidance for confidence classification (from IUCN 2020b).

Sources of uncertainty that influence the confidence rating	Presence of confounding effects	Study design	Data quality and type	Spatial and temporal scale	Coherence of evidence
High confidence: it is likely (approximately 90% chance) that the true impact category is equal to the assigned one	The likelihood of including confounding effects is low (i.e. it is unlikely that the level of impact would have been observed if the alien taxon was not introduced)	The study design would have allowed the detection of higher/lower impact magnitudes than the one assigned	There is relevant direct observational evidence to support the assessment; the data are reliable and of good quality	Impacts are recorded at the typical spatial and temporal scales at which the local native population can be characterised	All evidence points in the same direction (no contradictory evidence)
Medium confidence: there is potential for the true impact category to be different from the assigned one (approximately 65–75% chance of the assigned impact category being correct)	Confounding effects may be at least partly responsible for the observed impact (i.e. potentially the observed level of impact would still have happened if the alien taxon was not introduced)	The study design would not have allowed the detection of higher/ lower impact magnitudes than the one assigned (i.e. it cannot be reasonably excluded)	There is some direct observational evidence to support the assessment, but some of the data are inferred	Impacts are recorded at a spatial or temporal scale which may not be relevant to the scale over which the local native population can be characterised, but extrapolation or downscaling of the data to relevant scales is considered reliable or embraces little uncertainty	Most evidence points in the same direction, but some is contradictory or ambiguous
Low confidence: it is likely that the true impact category is different from the assigned one (approximately 35% change of the assigned impact category being correct)	The likelihood of including confounding effects is high (i.e. it is likely that the observed level of impact would have happened if the alien taxon was not introduced)	The study design does not allow any conclusions about higher or lower impact magnitudes and it is likely that the true impact magnitude is higher or lower	There is no direct observational evidence to support the assessment; data are of low quality	Impacts are recorded at a spatial or temporal scale which is unlikely to be relevant to the scale at which the local native population can be characterised, and extrapolation or downscaling of the data to relevant scales is considered unreliable or embraces significant uncertainties	Data are strongly ambiguous, or contradictory

Conclusions

Here we have provided clarifications to improve the understanding of the EICAT framework. We highlighted the problematic aspects of the initial EICAT framework and guidelines (Blackburn et al. 2014; Hawkins et al. 2015), which have been modified, but not explained, in the revised versions (IUCN 2020a, b). We also provided concrete examples and additional explanations on the impact assessment process.

It is, however, impossible to completely avoid differences in interpretation amongst assessors for some aspects of the framework. Therefore, we stress the importance of following the recommendations given by González-Moreno et al. (2019): assessors should be adequately trained, and continuously discuss and exchange their work with other assessors for feedback and review.

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